

The logo for RWDI is centered on a blue background. It consists of a square with a yellow border. Inside the square, the letters 'RWDI' are written in a large, white, bold, sans-serif font. The background of the square is a dark blue grid pattern that transitions into a lighter blue, textured pattern of diagonal lines in the bottom right corner.

RWDI



Reducing Stack Height – Understanding the Formation of Rooftop Re-circulation Regions

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Introduction

- The fundamental goal of stack design is to prevent contaminated exhaust from entering building air intake systems
- High volume flow and high exit velocity are common methods used to increase stack-to-intake dispersion
- This allows exhaust to escape roof top re-circulation zones, without significant increases in stack height

Introduction

- For specialty type exhaust stacks, low volume flow is often unavoidable
- Tall stacks may then be necessary to achieve the required dispersion

Introduction

- The re-circulation region that forms over the roof of tall rectangular buildings can be very large - *greater than 20 feet in many cases*
- It often engulfs the entire area of the roof
- This requires a combination of tall stacks, high flow rates and high exit velocity
- All of these scenarios can result in high energy costs



Presentation Outline

- Brief overview of how re-circulation regions are formed
- Discuss the concept of effective stack height as it relates to re-circulation regions
- Apply the concept of effective stack height to tall rectangular buildings using wind tunnel data to show that stack location can be optimized to increase exhaust dispersion
- Discuss the advantages for potential energy cost savings



Presentation Outline

and time permitting, discuss...

- Optimal air intake locations
- Impact of screen walls on re-circulation regions and exhaust dilution

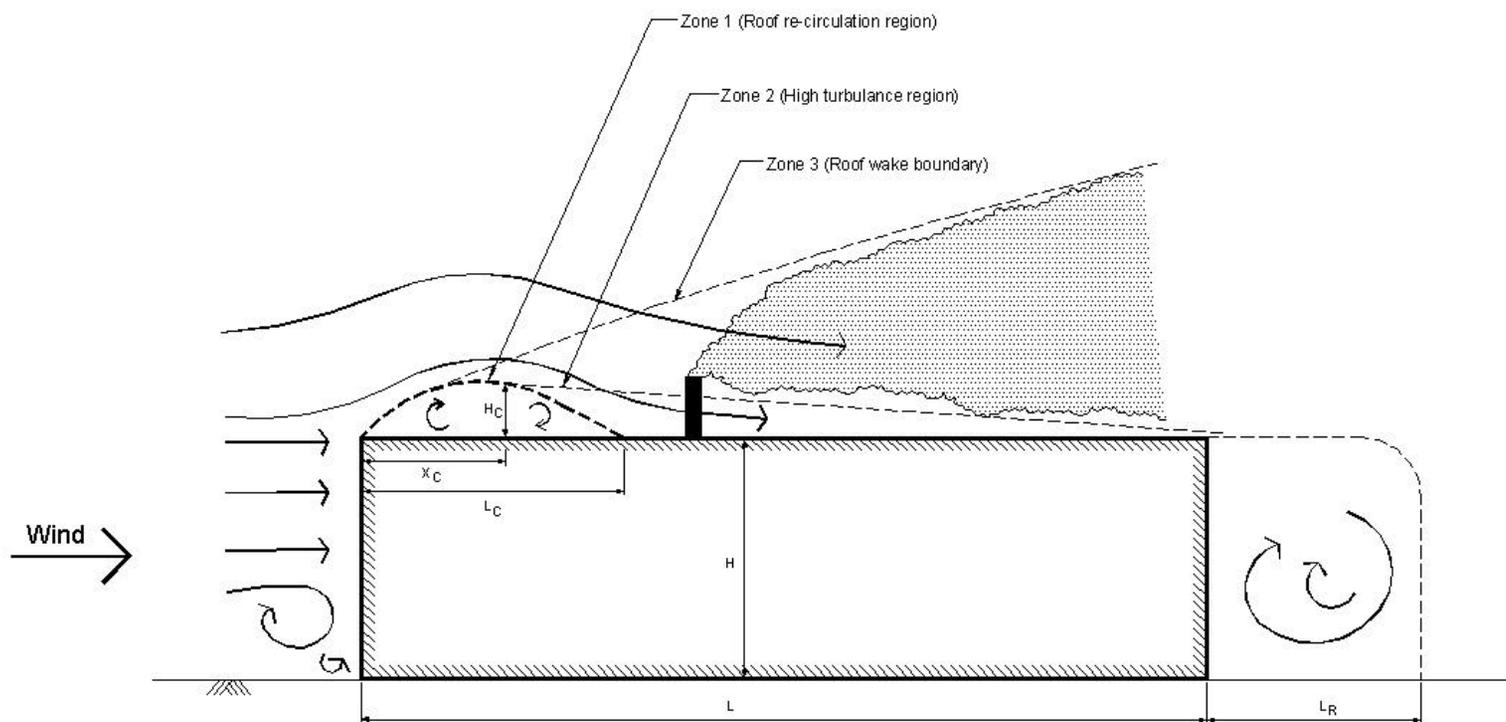


Re-circulation Regions

Overview

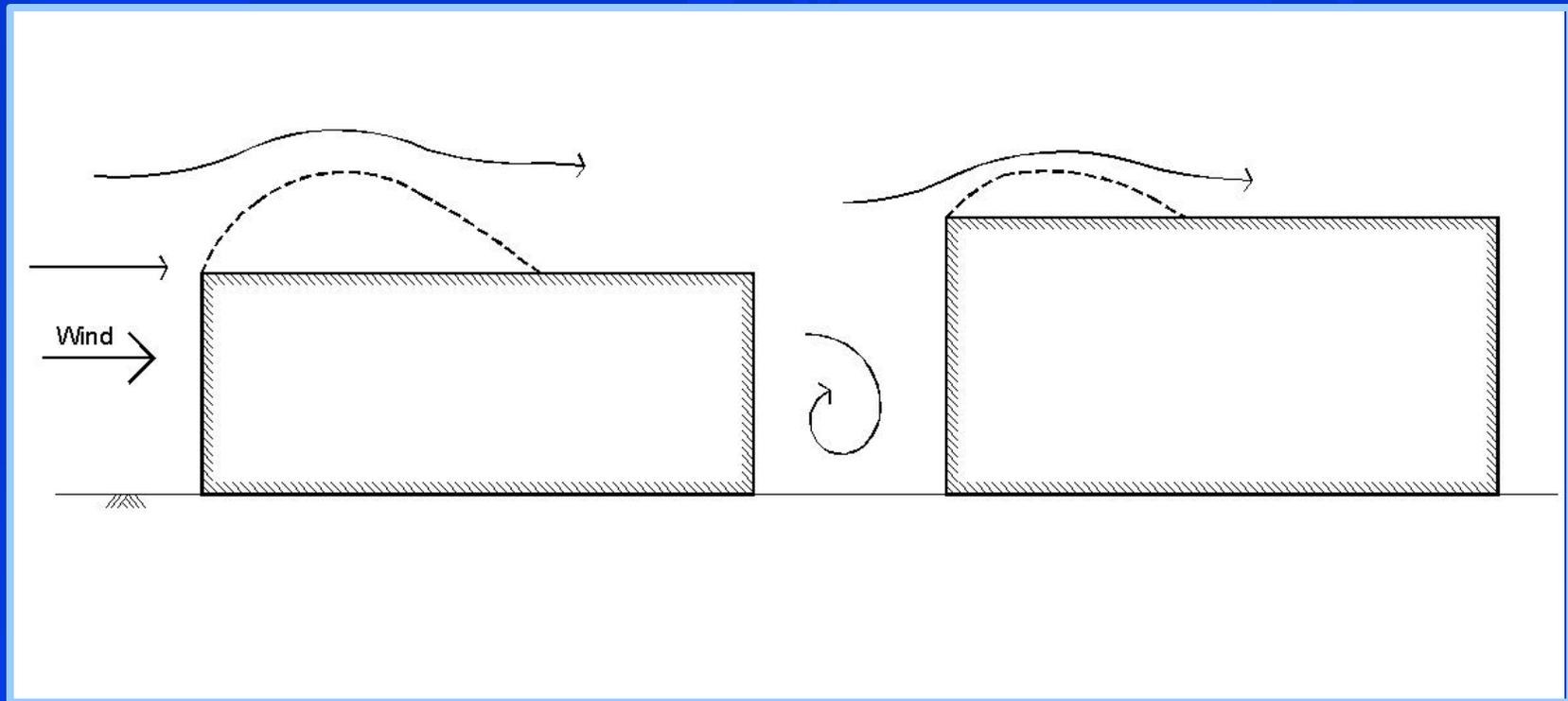
- American Society of Heating Refrigerating and Air-Conditioning Engineers (ASHRAE) provides guidance on stack design
- Prevent re-entrainment of contaminated air into building air intakes
- Discharge the exhaust at a height that is above the re-circulation region or “bubble” that forms over the roof

Re-circulation Regions

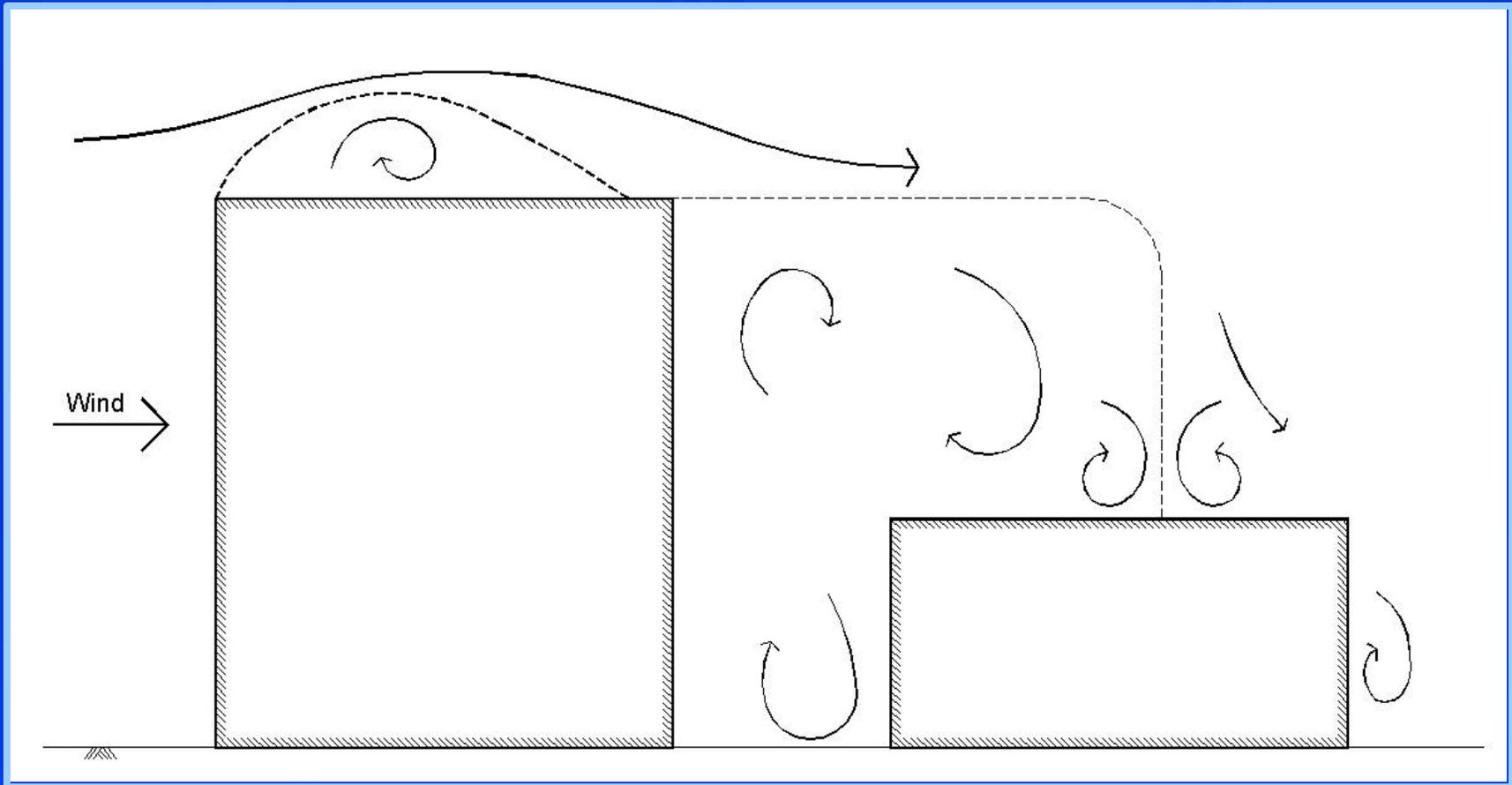


RECREATED FROM ASHRAE (1999) APPLICATIONS

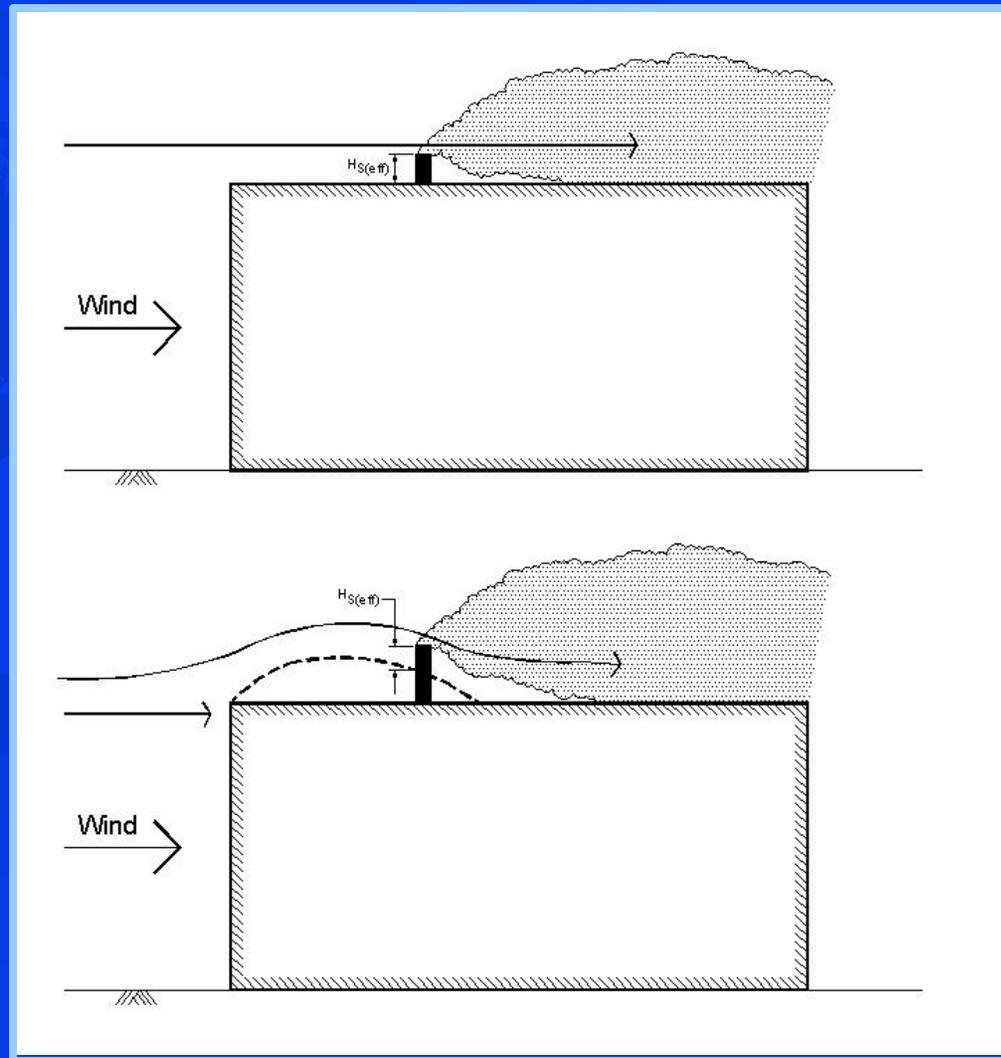
Upwind Building Effects



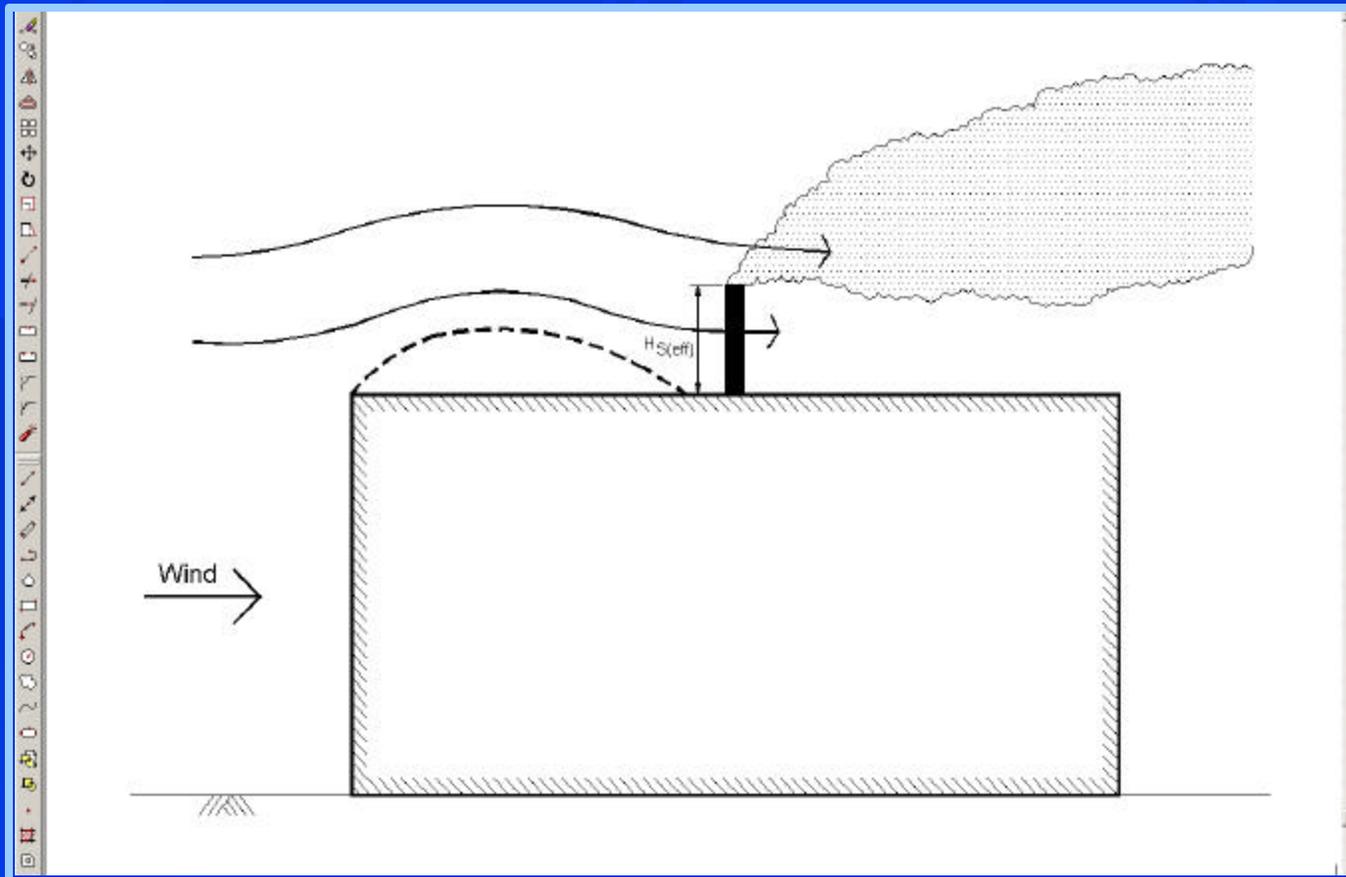
Taller Upwind Building



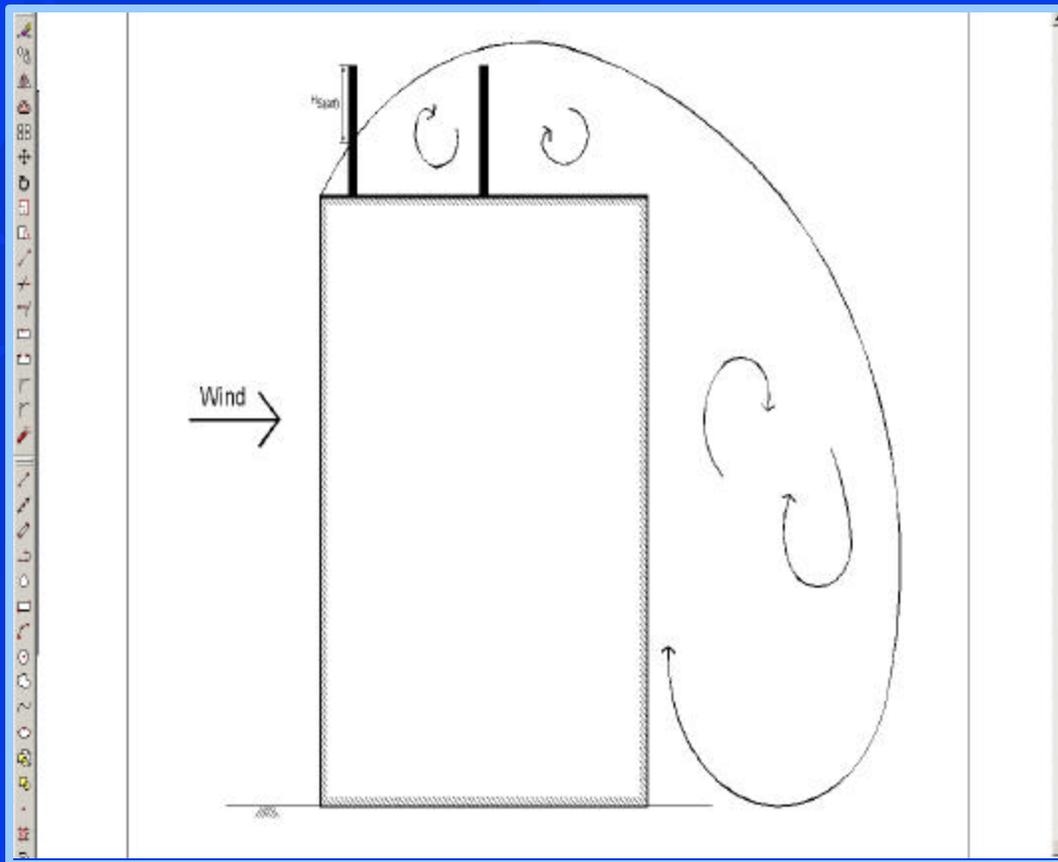
Effective Stack Height



Short Squat Buildings



Tall Rectangular Buildings





Wind Tunnel Program

Designed to demonstrate that:

- A set-back penthouse on a tall rectangular building results in a smaller and more streamlined re-circulation bubble
- A stack located on the upwind side of the bubble has more effective stack height
- Both effects provide increased exhaust dilution at rooftop receptors

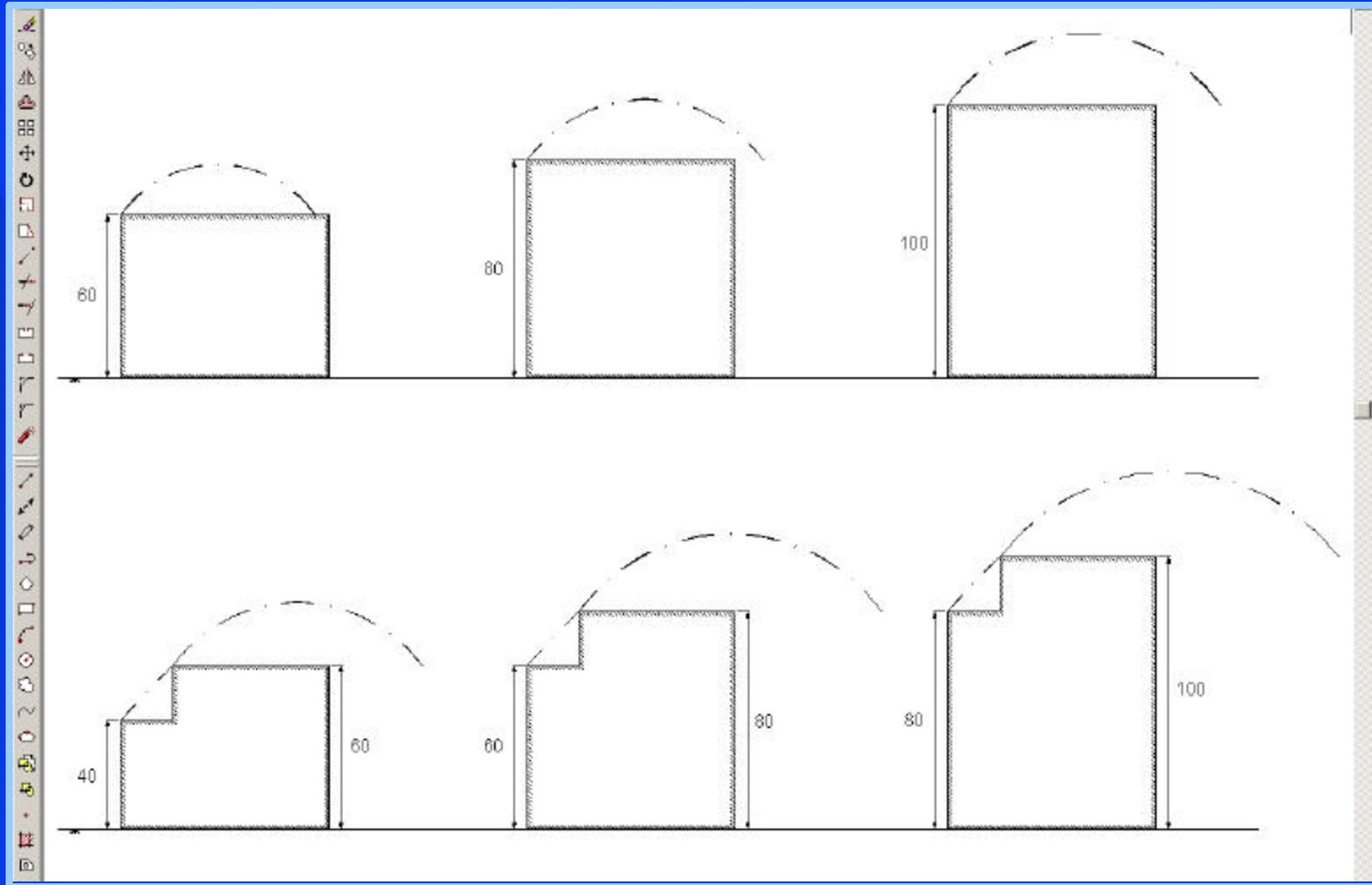
Test Parameters

- Two stack locations (A and B)
- Full scale stack heights 10, 15, 20 and 25 feet above roof
- Full scale building heights 60, 80 and 100 feet
- Full scale building footprint 160 feet by 80 feet

Test Parameters

- Non-buoyant plume, low volume flow rate (1,300 cfm) and high exit velocity (3,000 fpm)
- Full plume bend over was achieved
- Seven rooftop receptors and one down wind side wall receptor

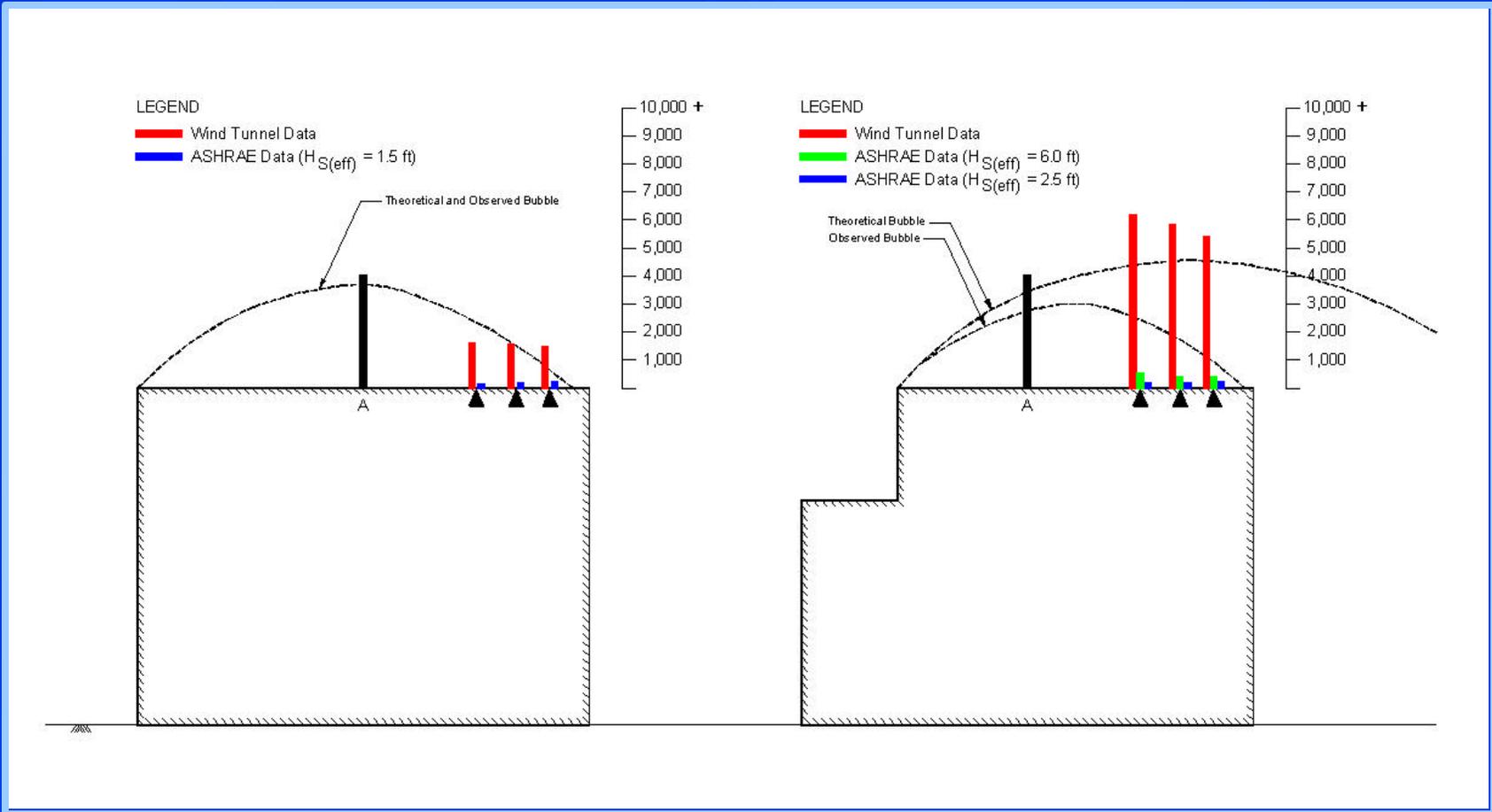
Summary of Building Configurations



Study Buildings

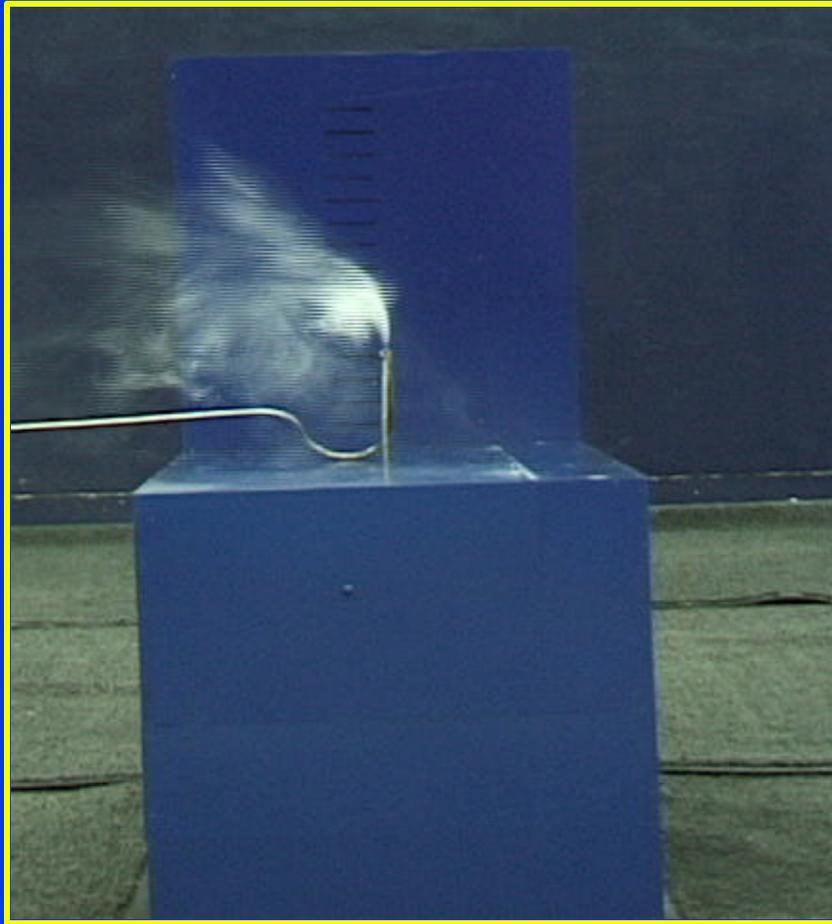


Effects of Roof Step



Stack A – 15 foot

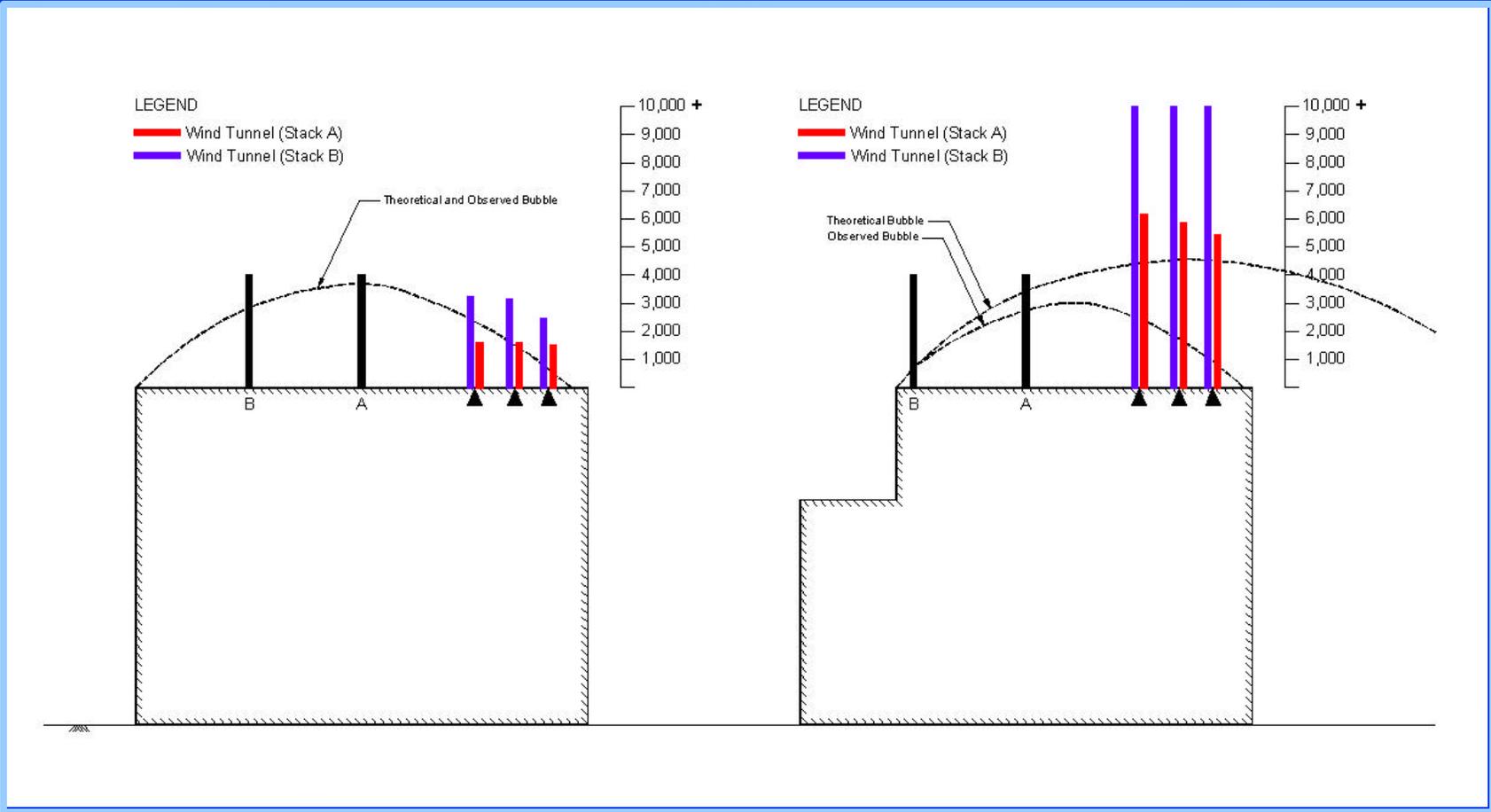
Block Roof



Stepped Roof

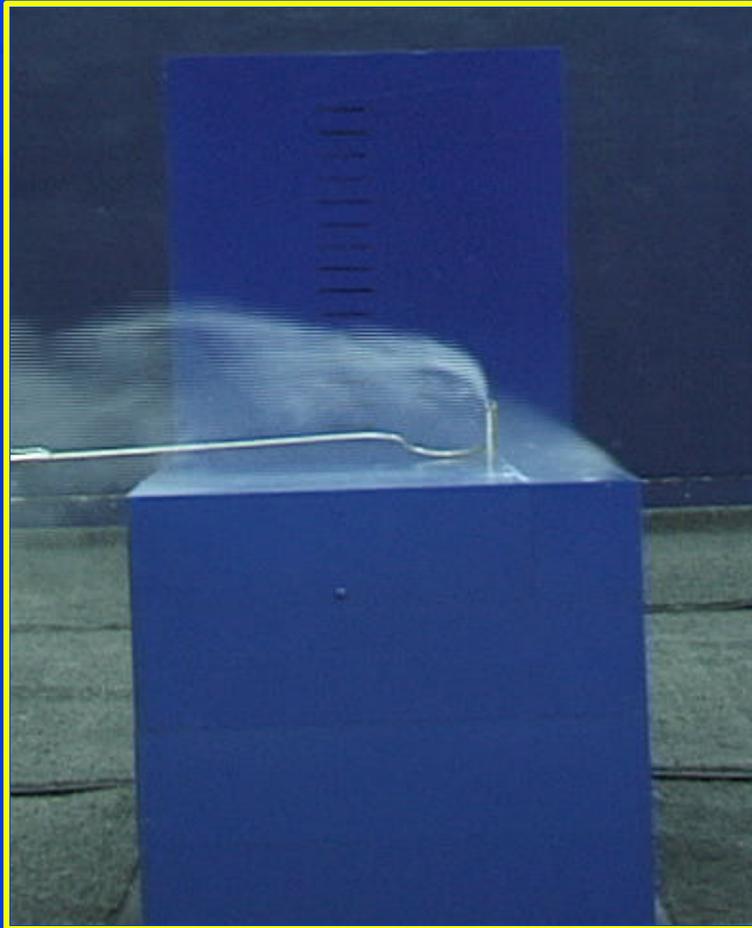


Effects of Stack Location

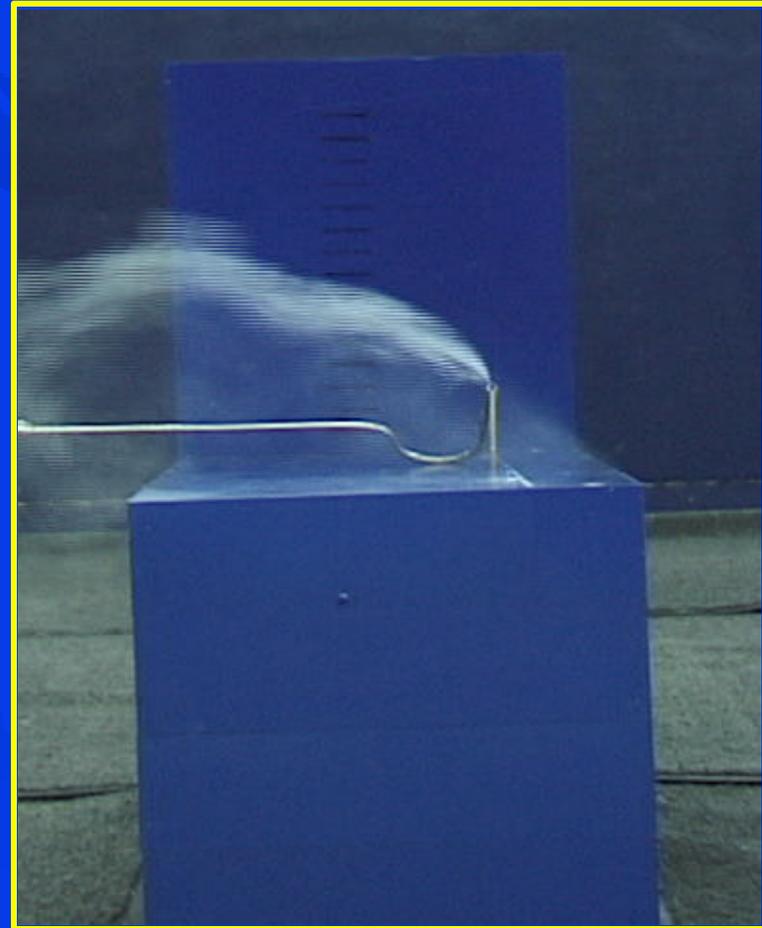


Stack B – Block Roof

10 foot stack

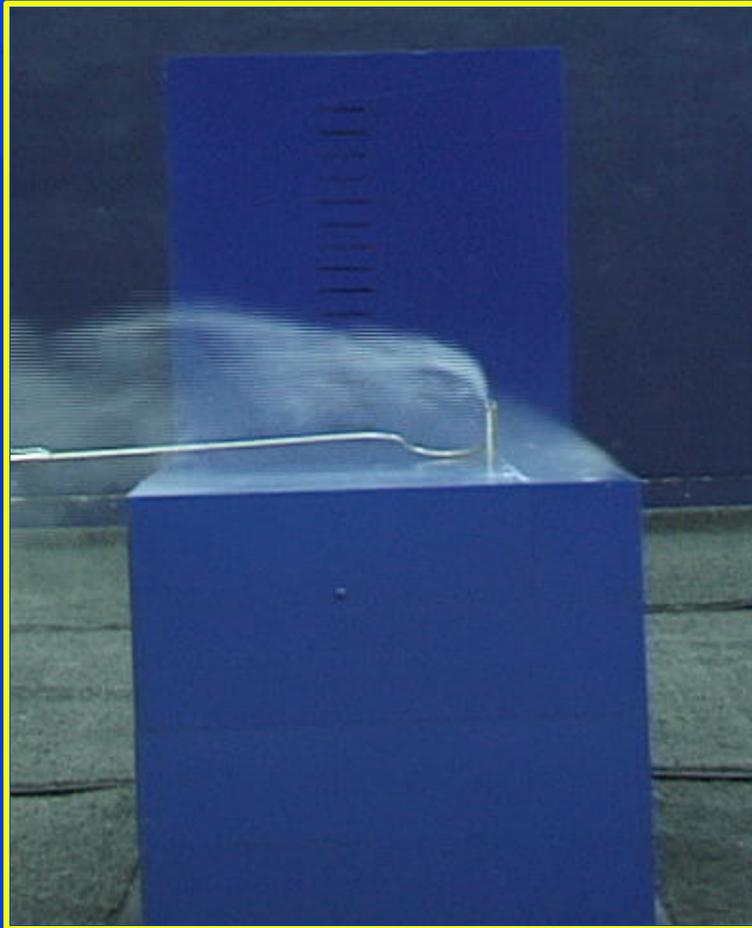


15 foot stack

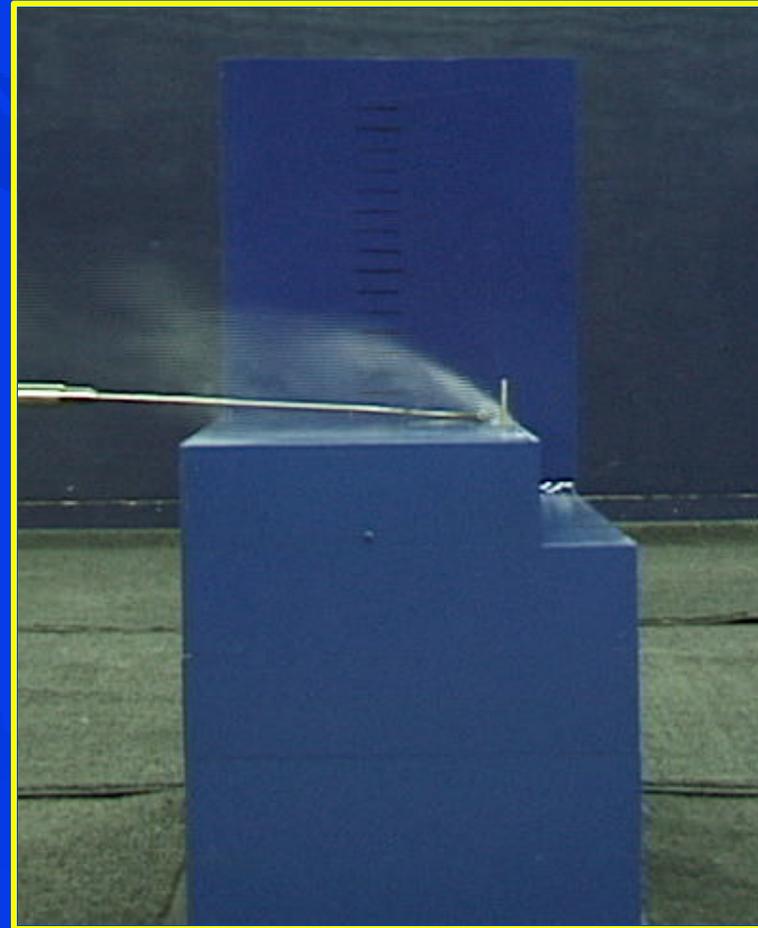


Stack B

10 foot stack block roof

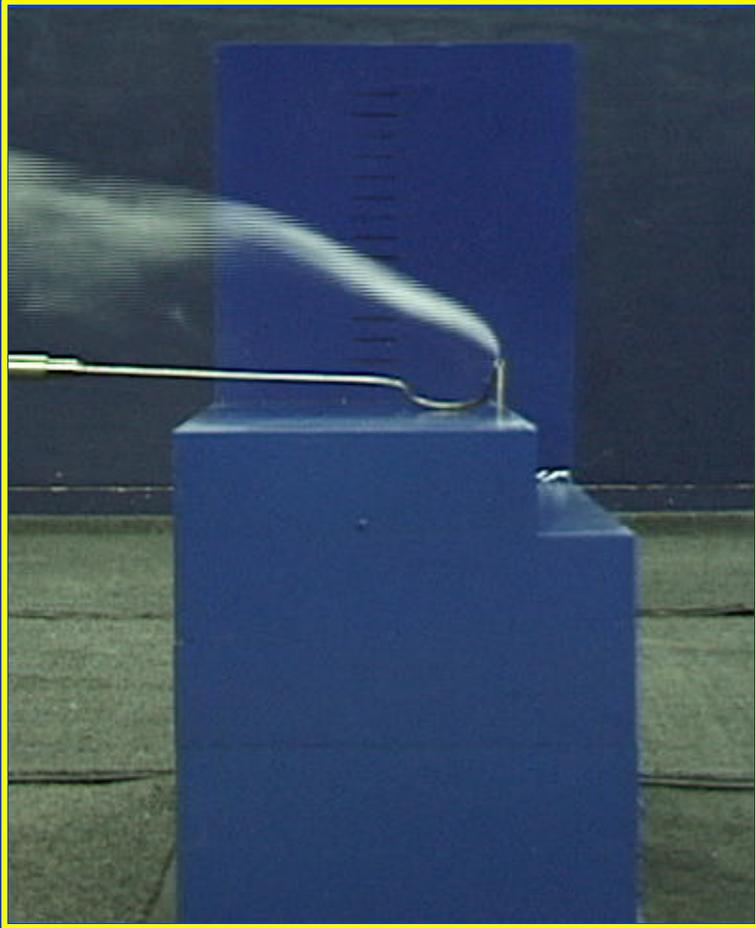


10 foot stack stepped roof

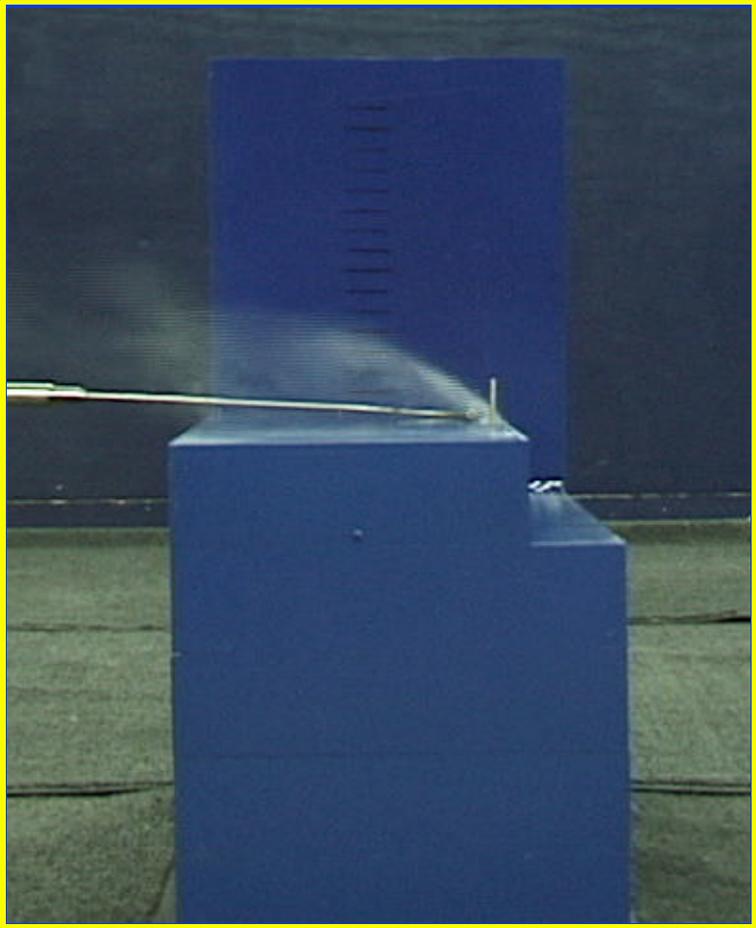


Stack B – Stepped Roof

Stack Plume



Re-circulation boundary



Discussion

- If a stack can be located so that you don't need:
 - Significant additional height
 - The provision of induced air
 - Increased exit velocity
- Then the system can be designed to provide more operational efficiency, such as reduced design requirements for exhaust fans
- This can lead to operational savings

Conclusions

- Exhaust stacks can be moved up stream of the recirculation bubble to increase effective stack height and dilutions
- Stepped back roof helps to reduce bubble height, providing increased effective stack height
- Bubble is also shifted downwind from the stacks also increasing effective stack height
- Increasing effective stack height provides operational flexibility

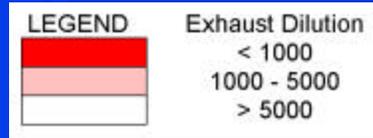


Summary of the Results

Taller stacks required for screen wall in all cases

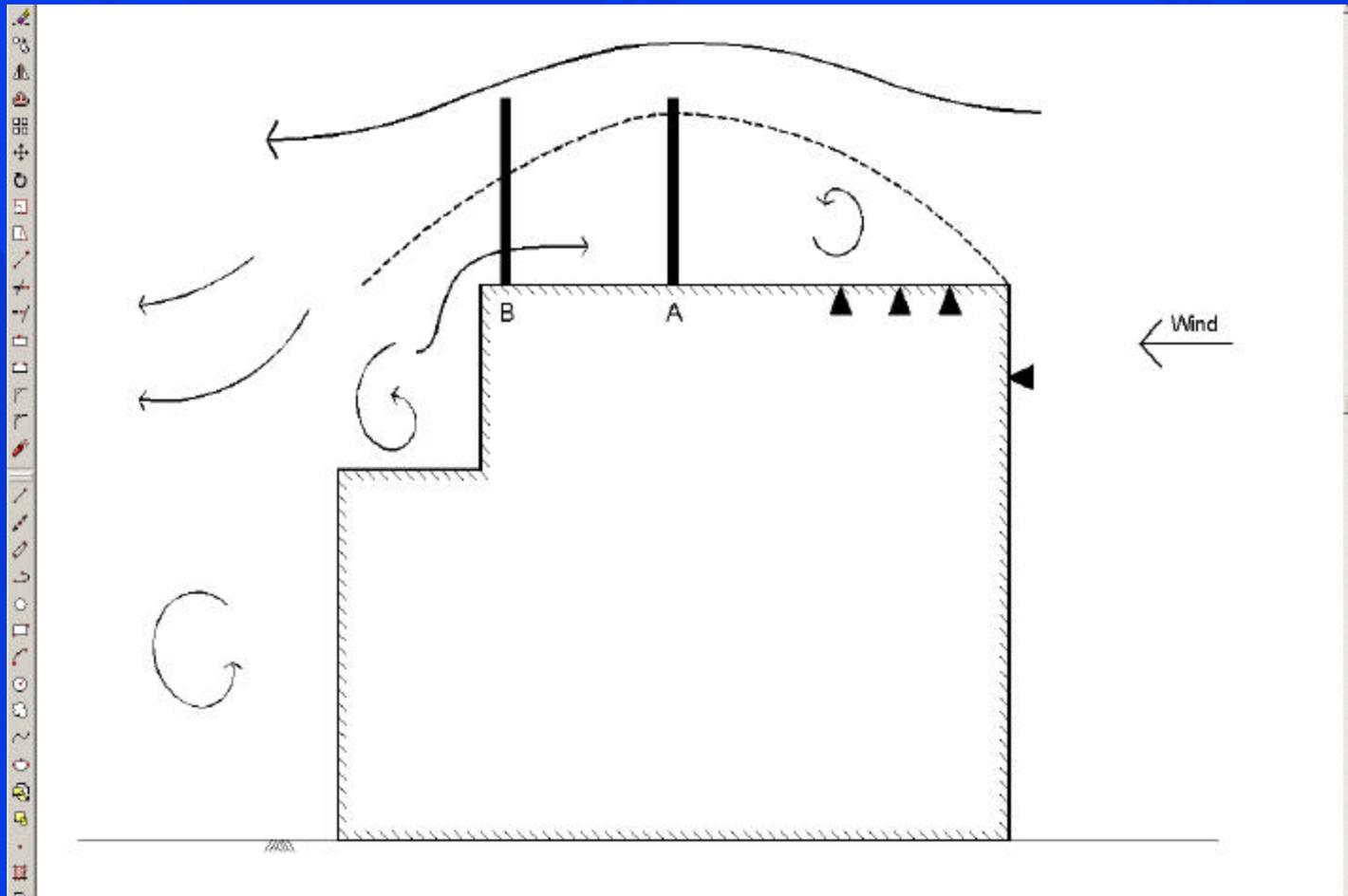
Location B is better than location A in all cases

Set-back roof is better than no set-back roof in all cases

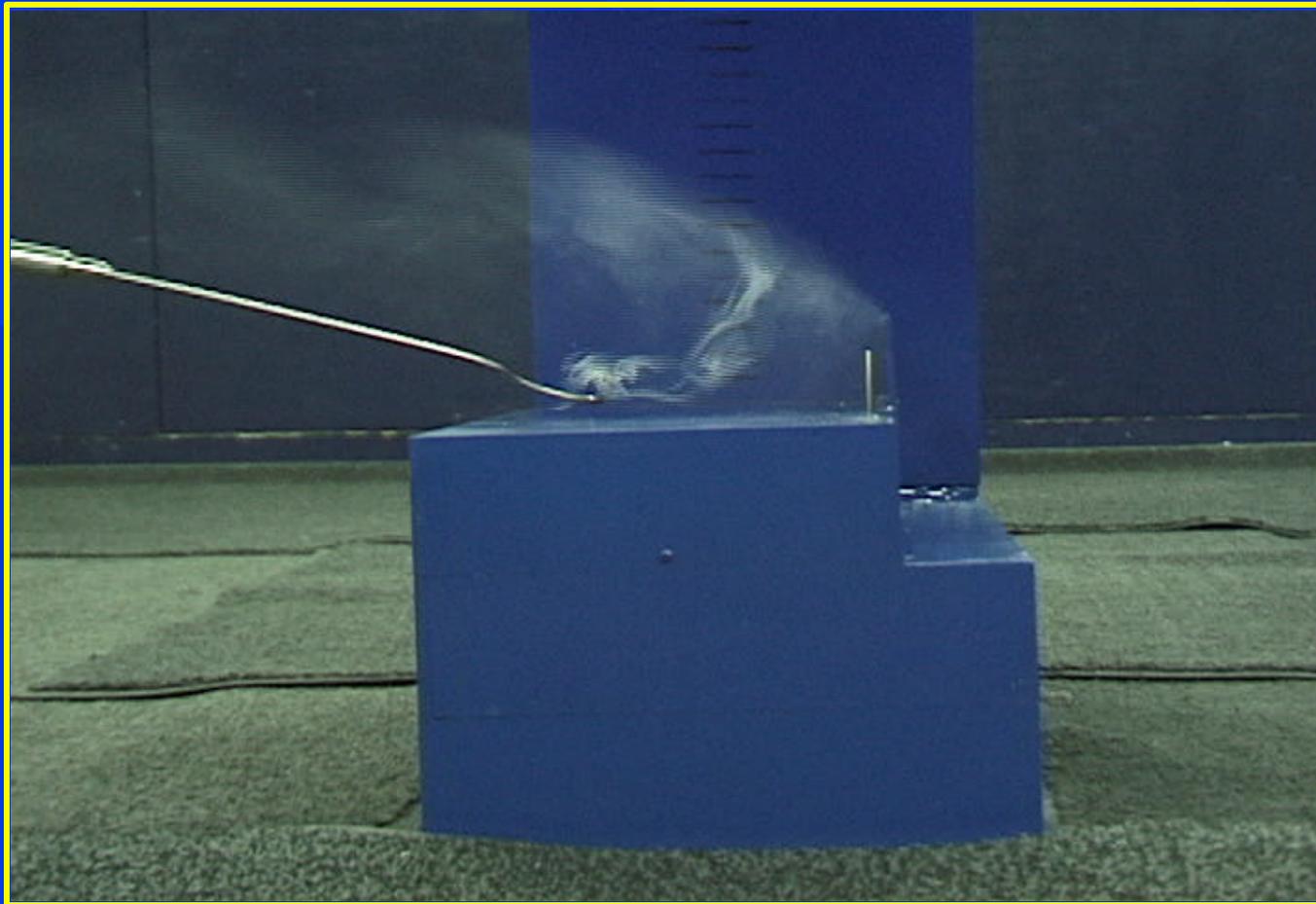


		STACK HEIGHT (feet)															
		10	15	20	25	10	15	20	25	10	15	20	25	10	15	20	25
		60 FEET Block				60 FEET Block, Screen				60 FEET Set-back				60 Feet Set-back, Screen			
		Stack A															
R1	1000	1472	2408	3300	4300	1424	1714	2021	2787	821	931	1000	1000	1278	1828	2407	3130
R2	1000	1384	2345	3200	4200	1350	1640	1721	2144	922	991	1000	1000	1052	1704	2228	2887
R3	1000	1153	2055	3000	4000	2057	2006	1852	2171	513	1521	1000	1000	2155	2234	2639	3550
R4	1000	989	1791	2700	3700	2039	1898	1824	2251	483	1294	1000	1000	2153	2145	2375	3224
R5	1000	844	1700	2600	3600	2031	1824	1898	2351	480	1029	1155	1000	2294	2424	2252	3200
R6	1000	721	1552	2500	3500	2599	2036	2381	2354	520	1175	1000	1000	2000	2855	2708	4000
R7	1000	628	1400	2400	3400	2668	2179	2441	2622	560	1078	1000	1000	2001	2768	2808	4200
R8	1000	552	1300	2300	3300	1300	1300	1300	1000	610	610	1000	1000	1800	1800	1300	1000
		Stack B															
R1	1000	1070	1900	2800	3800	2471	2495	2864	1000	3729	1000	1000	1000	2228	2828	3817	5245
R2	1000	1075	2078	3000	4000	2338	2285	2617	1000	2485	1000	1000	1000	2152	2255	2615	4188
R3	1000	1043	2419	3400	4400	2628	2703	3045	1000	3485	1000	1000	1000	3494	3624	3738	5244
R4	1000	986	2698	3700	4700	2579	2488	2781	1000	2889	1000	1000	1000	3151	3175	3415	4484
R5	1000	944	2448	3200	4200	2275	2423	2585	1000	2190	1000	1000	1000	2133	2895	3543	4386
R6	1000	844	2322	3152	4000	2207	2820	3078	1000	1940	1000	1000	1000	2008	3225	4243	5200
R7	1000	769	2080	2751	3600	2756	2758	3479	1000	1786	2085	1000	1000	2407	3259	4221	5480
R8	1000	1000	1000	1000	1000	1300	1300	1300	1000	1000	1000	1000	1000	1800	1800	1300	1000
		80 FEET Block				80 FEET Block, Screen				80 FEET Set-back				80 Feet Set-back, Screen			
		Stack A															
R1	1000	1216	2159	3095	4095	1467	1832	2121	2280	940	1195	1000	1000	1521	2103	2525	2783
R2	1000	1086	1981	2858	3858	1652	1888	1853	2173	823	1587	1000	1000	1524	2208	2284	3484
R3	1000	9084	2244	3200	4200	2268	2167	2161	2295	901	1189	1000	1000	2028	2698	3251	3718
R4	1000	750	1732	2700	3700	2118	2096	2049	2295	940	1190	1000	1000	2157	2757	2854	3814
R5	1000	600	1408	2300	3300	2175	2195	2194	2295	871	1067	1158	1000	2258	2804	2827	2780
R6	1000	503	1037	1924	2843	2718	2828	2443	2602	813	1122	1000	1000	2028	3524	3852	3384
R7	1000	406	1005	1955	2822	2668	2833	2585	2847	752	1130	1000	1000	2103	3584	3732	3629
R8	1000	1000	1000	1000	1000	1300	1300	1300	1000	1000	1000	1000	1000	1800	1800	1300	1000
		Stack B															
R1	1000	1071	2556	3600	4600	2511	2573	3083	1000	3638	1000	1000	1000	2728	2898	2957	3581
R2	1000	1080	2818	3900	4900	2522	2248	3187	1000	2422	1000	1000	1000	2701	2808	2440	4588
R3	1000	1058	3004	4100	5100	3178	2830	3659	1000	3758	1000	1000	1000	3758	3413	3852	5100
R4	1000	986	3268	4400	5400	2662	2300	3082	1000	2785	1000	1000	1000	3438	2858	2954	5212
R5	1000	924	3008	4200	5200	2679	2280	3082	1000	2287	1000	1000	1000	3433	2868	2798	4891
R6	1000	844	2802	3700	4700	3203	2824	3785	1000	2824	1000	1000	1000	4141	3824	3228	5787
R7	1000	769	2534	3228	4000	3428	3882	4187	1000	2176	1000	1000	1000	4205	3711	3387	5886
R8	1000	1000	1000	1000	1000	1300	1300	1300	1000	1000	1000	1000	1000	1800	1800	1300	1000
		100 FEET Block				100 FEET Block, Screen				100 FEET Set-back				100 Feet Set-back, Screen			
		Stack A															
R1	1000	1226	1924	2640	3400	1508	2236	2983	3415	984	1391	1000	1000	1316	1884	2500	3187
R2	1000	1127	1758	2458	3218	1652	2627	3429	2844	758	1594	1000	1000	1528	1958	2429	2779
R3	1000	1110	1931	2645	3400	2256	2627	2673	3222	571	1535	1000	1000	1524	2528	3120	3412
R4	1000	1079	1547	2256	3000	2398	2322	2547	2739	703	1391	1000	1000	1706	2680	2804	3340
R5	1000	1038	1308	1908	2600	2213	2225	2200	2580	691	1170	1000	1000	2528	2825	2825	3365
R6	1000	1225	1148	1475	2018	2534	2806	2882	3288	781	1180	1000	1000	3828	3700	3203	3743
R7	1000	1271	1241	1625	2018	2744	3028	2989	3186	682	1538	1000	1000	3757	3229	3613	3821
R8	1000	1000	1000	1000	1000	1300	1300	1300	1000	1000	1000	1000	1000	1800	1800	1300	1000
		Stack B															
R1	1000	1131	2738	3900	5100	2754	2737	3082	1000	4113	1000	1000	1000	2702	3229	3477	5522
R2	1000	1074	3438	4700	6000	2505	1827	3088	1000	2240	1000	1000	1000	2642	3113	3325	4579
R3	1000	1157	3857	5200	6600	3368	2327	3888	1000	3822	1000	1000	1000	3718	3804	3814	5246
R4	1000	1118	2158	3000	3900	3279	2192	3644	1000	2626	1000	1000	1000	3457	3620	3388	4878
R5	1000	1078	1918	2700	3600	2507	2154	3481	1000	1000	1000	1000	1000	3391	3257	3426	4836
R6	1000	1222	2062	2900	3800	2545	2795	3887	1000	1000	1000	1000	1000	3568	3713	3833	5069
R7	1000	1248	1952	2800	3700	3802	3620	4248	1000	1000	1000	1000	1000	4051	3884	4136	5000
R8	1000	1000	1000	1000	1000	1300	1300	1300	1000	1000	1000	1000	1000	1800	1800	1300	1000

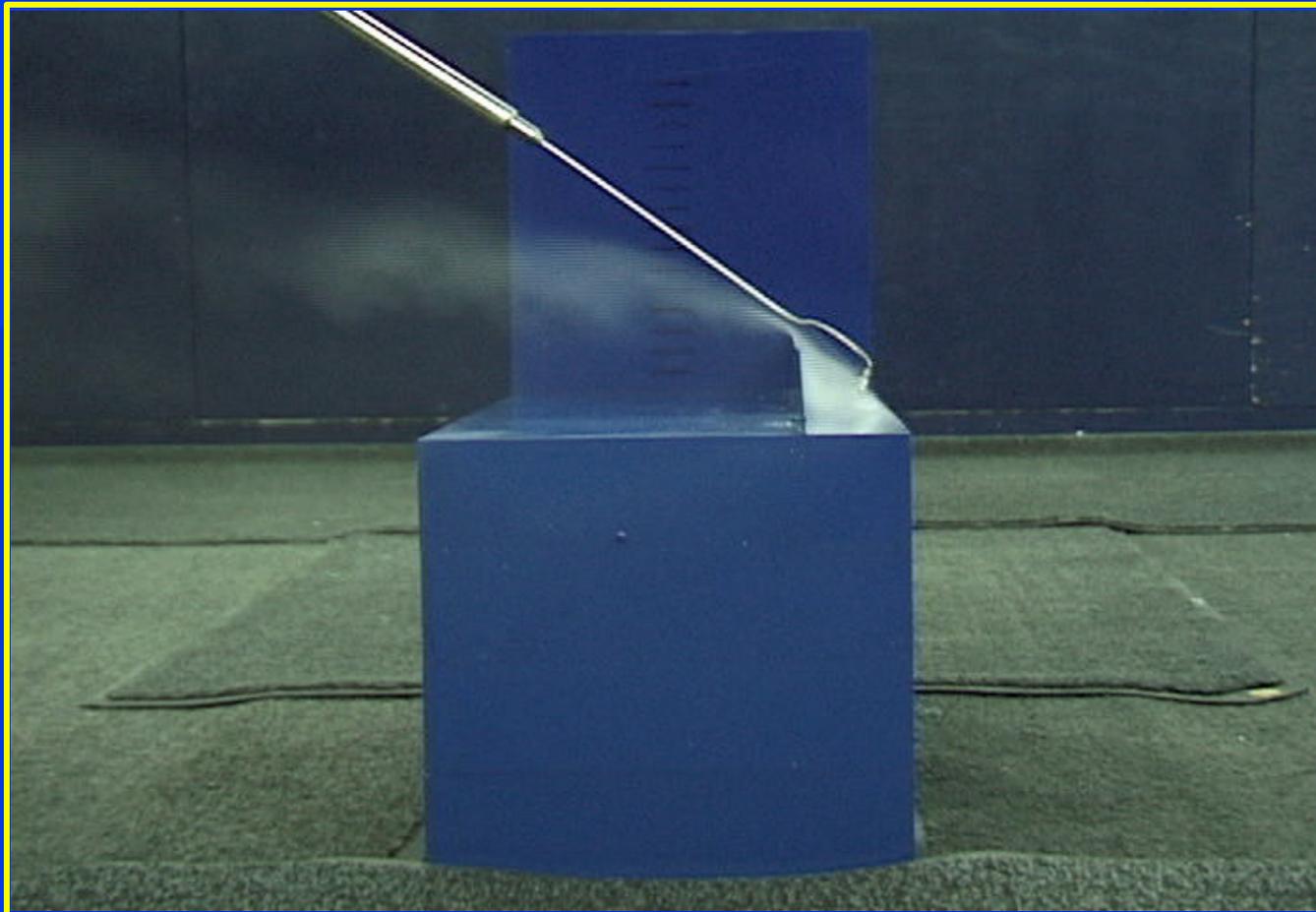
Intake Locations



Still from video



Still from video





Questions.....